Deployments Scenarios of 5G Networks

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ABSTRACT

Traditionally, interference and coexistence studies of cellular systems tackle their emerging issues without taking into account their duplex modes. Nevertheless, for duplex-based networks in general and for Long Term Evolution (LTE) in particular, it is quite important to consider the impact of duplex modes of both interfered and interfering cells on total emitted inter-cell interference power encountered. LTE, as a fourth generation radio, supports both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) schemes, while half-duplex mode being additional option introduced to LTE in certain network operations. In this work, the imapact of inter-duplexing overlap is analyzed and account for in the total emitted interference. Coexistence guidelines in 2.6 GHz frequency band will be also given and explained.

Keyword:

Duplex Overlap

Interference

4G

Coexistence

1. INTRODUCTION

The increasing demand for high capacity networks has forced to develop better, faster and more cost-effective spectral resources [1]. Recently, the offered channel bandwidths of the networks have grown significantly from 200 KHz in Global System Mobile (GSM) to 5MHz in Universal Mobile Telecommunications System (UMTS)/High Speed Packet Access (HSPA), and the Modulation and Coding Schemes (MCSs) have accordingly grown more sophisticated and efficient [2]. However, having the present bandwidth and intricacy of technologies like HSPA, it will be extremely challenging to gain more spectrum by merely increasing the channel bandwidth without turning the underlying technology itself enormously complex [3].

The Long Term Evolution (LTE) of UMTS is the evolutionary step in moving forward from the third (3G) to the fourth generation (4G) cellular services and to address operators' demands [4]. Consequently, the World Radio Conference in 2007 (WRC-07) of the International Telecommunication Union for Radio-communication (ITU-R) has earmarked various frequency bands for the current and future wireless systems [5]. The 2.6 GHz band (2500-2690 MHz) is one of such frequency bands [6].

Lately, the interest of wireless networks operators in the band 2.6 GHz band has increased considerably, mainly due to the coverage and spectral benefits of the band 2.6 GHz [7]. This is mainly ascribed to the coverage and spectral benefits of the band 2.6 GHz. Indeed, LTE deployment choices in the band 2.6 GHz are gaining great momentum over other competing technologies [8]. This is mostly attributed to LTE's flexible deployment and re-farming choices, which allow operators to re-use their existing Third Generation (3G) spectra [7].

Notably, LTE is being deployed in bands that allow multiple types of Radio Frequency (RF) access: Time Division Duplex (TDD) with different transmit / receive duty cycles, Frequency Division Duplex (FDD). This technology blend presents coexistence/colocation challenges that differ from previous cellular bands [9].

Therefore, the risk of inter-cell interference between LTE radio installations has increased in step with the increased use of LTE deployments in the 2.6 GHz band for both voice and data applications [10]. Furthermore, the augmented demographic crowd has given rise to a situation in which systems that transmit and receive radio signals over co- or adjacent frequencies are often placed so close to one another that the risk of unintentional interference is very great [11].

Traditionally, interference and coexistence studies of cellular systems tackle their emerging issues without taking into account their duplex modes [10]–[15]. Nevertheless, for duplex-based networks in general and for LTE in particular, it is quite important to consider the impact of duplex modes of both interfered and interfering cells on total emitted inter-cell interference power encountered. In this work, the imapact of inter-duplexing overlap is analyzed and accounted for in total emitted interference. Coexistence guidelines in 2.6 GHz frequency band will be also given and explained.

2. RESEARCH METHODOLOGY

The inter-cell interference transmitted from an interfering base station to a victim one is a function of several parameters whose impact on interference can either be positive (boosting) or negative (hampering); as expressed below:

$$i=p_{Tx}+G_{Tx}+G_{Rx}-32.log(f)+20log(d)-ACIR+A_h+Int_{dup} \qquad (1)$$

Where i is the interference (dBm) transmitted from the interfering cell to other victim ones, p_{Tx} is transmission power (dBm) of interfering cell, G_{Tx} and G_{Rx} are interferer's transmitter and victim's receiver antenna gains (dBi), respectively, f is the radio frequency (MHz) of interfering transmitter, d is the distance (km) between interfering and victim cells, $ACIR$ and A_h are Adjacent channel interference power ratio and deployment environment clutter loss, respectively. More details about the popular $ACIR$ and A_h are found in [16], while Int_{dup} is the inter-duplex overlap factor (dB), as show in Figure 1.

Note that the "up" and "down" arrows shown in Figure 1 denote interference boosting and attenuating characteristics, respectively, and the use of double-arrowed factors in Figure 1 implies changeable states of their corresponding factors.

Figure 2 illustrates major inter-cell interference scenarios in 2.6 GHz along with their corresponding overlapping regions.

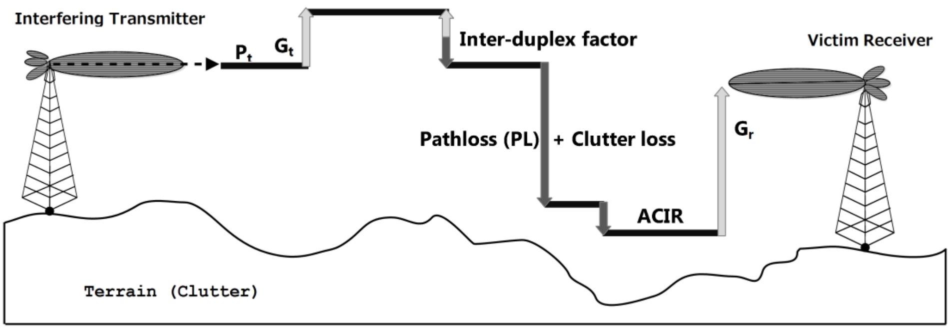


Figure 1. Power flow of interfering signals towards victim receiver (factors in linear units)

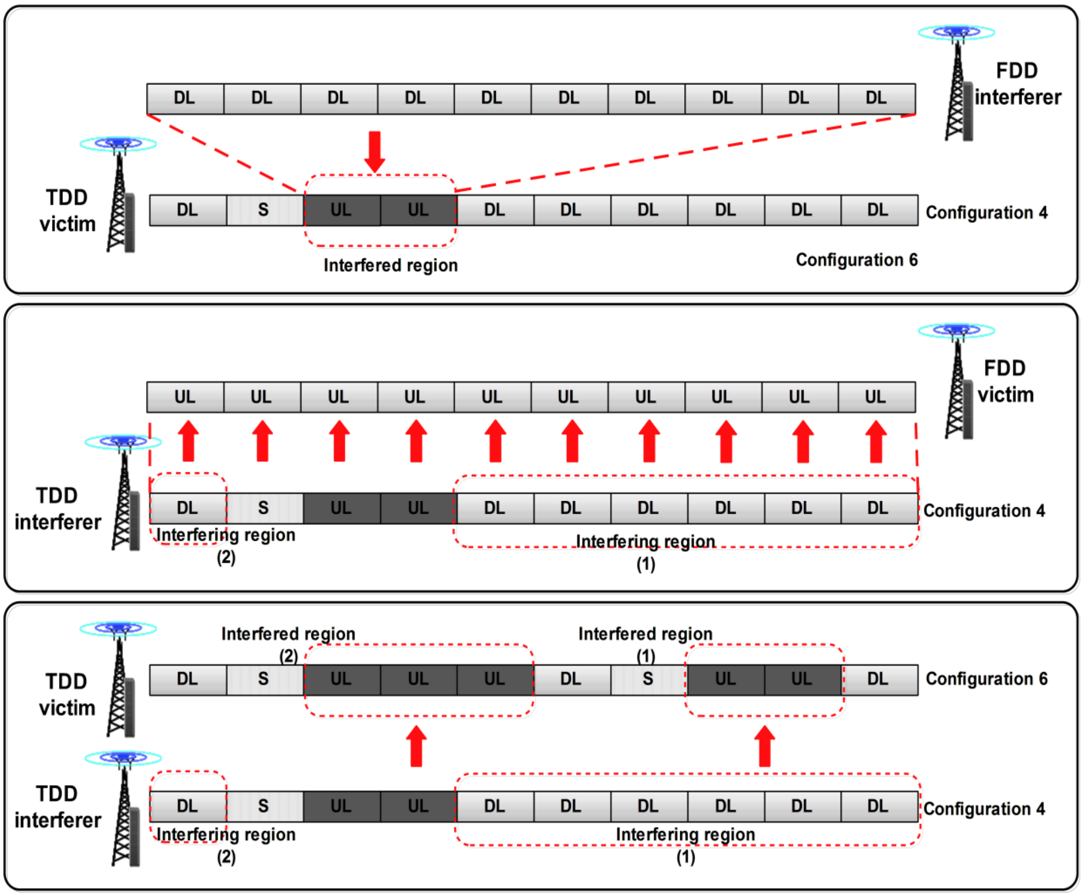


Figure 2. Inter-duplex overlapping scenarios in 2.6 GHz frequency band

For any coexisting LTE systems, Table 1 provides corresponding Int_{dup} values for potentially overlapping channels. Thus, when an LTE cell of a certain duplex mode interferes with another LTE cell of similar or dissimilar duplex schemes, it is necessary to account for frame configurations of overlapping cells. This is because FDD Uplink/ Downlink (UL/DL) subframes are uniquely distinguished during transmission, while TDD-UL/DL subframes are all located within the same frame. This therefore ensures that the impact of relevant subframes (either UL or DL) is only considered in the calculations, and not both, as shown in Figure 2.

It can be seen from Figure 2 that not all TDD subframes contribute to inter-cell interference situation nor all being victimized. And from victim receiver perspective, only TDD receiving subframes are vulnerable to transmitter's interfering subframes, the remaining subframes (namely, transmitting (DL) and special subframes (S)) are intact. Alternatively, only TDD transmitting subframes interfere with other victim receiving subframes when TDD-based system is the aggressor. However, DL-to-UL ratio (DL/UL) of TDD victim receiver and transmitter should be taken into account when weighting total resulting interference except for FDD-based victim, where transmitting and receiving links are distinctively separated in frequency domain. This implies that the total 10 subframes of FDD frame of an LTE victim receiver will be interfered by other FDD or TDD aggressors, and therefore all are considered. This explains the elimination of DL/UL ratio in Table 1 where FDD receiver is being victimized by other FDD transmitters. Lastly, it should be noted that unity inter-duplex overlapping factor is also possible in TDD victim scenarios, and this is ascribed to the employment of similar subframe configurations of the two overlapping TDD systems, as depicted in Figure 1 and the first entry in Table 1.

Table 1. The Inter-duplex overlap ratio for potentially LTE overlapping systems

Inter-duplex Overlap Rasio (Linear units)		
	Interfering Channel	
Victim Channel	TDD	FDD
TDD	1 if both victim & interferer use the same subframe configuration; Otherwise, it is the product − − of the two TDD frames	−) of victim TDD subframes
FDD	−) of interfering TDD subframes	1

In view of Figure 2, the entries of Table 1 can be justified as follows. When an FDD transmitter interferes with another FDD victim receiver, the 10 subframes of the aggressor will overlap the 10 subframes of FDD victim receiver. However, the interference of an FDD aggressor with another TDD receiver will not affect all TDD subframes (as some TDD subframes, namely, downlink ones will not receive harmful power on their corresponding channels). Therefore, total received interference must be weighted by the ratio of the small number (S) of either UL or DL of victim TDD subframes to the big number (B) of either UL or DL of the same victim TDD subframes. In line with upper pane of Figure 2, this implies that the total interference is reduced by the ratio $\frac{2}{7}$ (linear units).

Similarly, when TDD is the type of an interfering transmitter and FDD is the victim receiver, total interference is reduced in the same above-mentioned way except for the number of relevant subframes. In view of the middle pane of Figure 1, this means that all UL subframes of FDD receiver will be receiving interference; however, only 7 DL subframes of the TDD aggressor will transmit harmful power- the rest 2 UL subframes will not transmit anything. Accordingly, the ratio of $\frac{2}{7}$ is also the resulting interference reduction factor.

The special case of two overlapping TDD frames is illustrated in the lower pane of Figure 2 where a TDD type transmitter interferes with another TDD type receiver. In this case, total transmitted and received interference is decided by both overlapping TDD systems as neither the transmitter will transmit through its 10 subframes nor the victim receiver will receive on its 10 subframes. Therefore, ratios of both TDD cells must be taken into account, that is, the ratio $\frac{S}{B}$ of interfering TDD transmitter multiplied by the ratio of victim receiver (in linear domain). As a result, lower pane scenario of Figure 1 will give rise to the ratio $(\frac{2}{7} \times \frac{3}{5})$. The remaining number of special subframes does count since these subframes are for UL-to-DL transition purposes and vice versa.

The term Int_{dup} in Equation 1 is the logarithm of the ratio $(\frac{S}{B})$ as expressed as follows:

$$Int_{dup}=10log(\frac{S}{B}) \qquad (2)$$

where Int_{dup} is inter-duplex overlapping factor, S and B are the *small* and *big* numbers of TDD subframes, respectively, regardless of their duplex type.

2.1. System Degradation and Sharing criteria

System degradation is a term used to describe sensitivity degradation level in any victim receiver after being interfered by an external interference. In other words, it is a measure of how badly a victim receiver performance becomes in any interference situation and calculated as the noise rise due to the received interference.

For two LTE systems to coexist, a 1 dB increase in receiver noise floor caused by unwanted signal of 6 dB below victim receiver noise floor is the peak degradation level that can be tolerated by the system [17], as depicted in Figure 3.

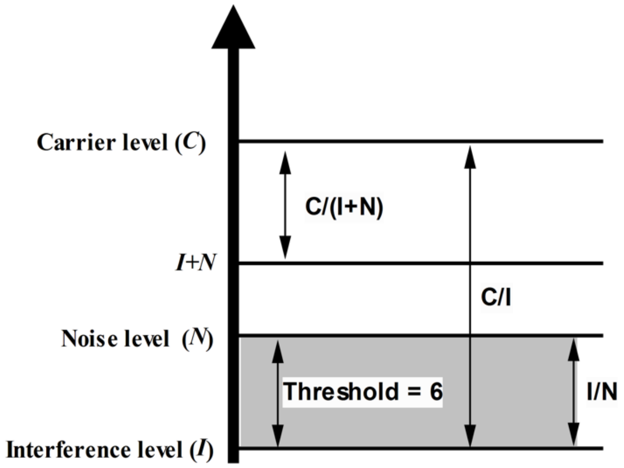


Figure 3. Interference protection criteria

The interference-to-noise power ratio (I/N= -6 dB) is used in this work as sharing threshold. This is also called interference protection criteria (IPC), beyond which coexistence and/or colocation situations of LTE base stations are not feasible [8].

2.2. LTE System Simulation Parameters

In line with [10], the considred LTE base stations are configured such that worst case scenarios can be realized in 2.6 GHz frequency band. Therefore, the parameters in Table 2 are used throughout the simulatios.

For the sake of more emphasis on the impact of inter-duplex overlap, one transmitting antenna is employed in the disturbing transmitter. Furthermore, the two cells feature antennas heights of 15 m above local ground level, whose isotropic gains are similar, namely 17 dBi.

A fully loaded (100 %) interferer's traffic condition is assumed. These amounts of traffics denote cell's instantaneous traffic while being delivered to users in terms of total cell's physical resources, that is, physical resource blocks. System load of 100% denotes 100% usage of cell's physical resources, while 30% and 80% traffics imply less utilized cell's spectral resources, which in turn gives rise to reduced power transmission of interfering cell [6].

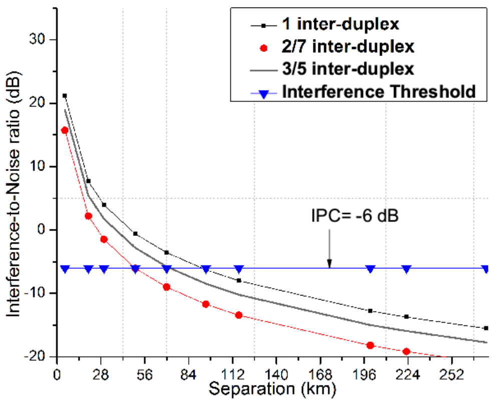
Victim Cell's transmission bandwidths of 1.4, 5, 10 and 20 MHz are chosen as the most potential bandwidths being deployed by LTE operators [7]. Notably, those bandwidths are significantly different from channels bandwidths; as the latter (channel BW) accounts for total cell's spectral resources, while the former (transmission BW) accounts only for transmitted resources. Finally, special subframe configuration 0 and 5 are chosen for TDD cell operations due to worst-case rationales [18].

Table 2. Simulation parameters of LTE base stations

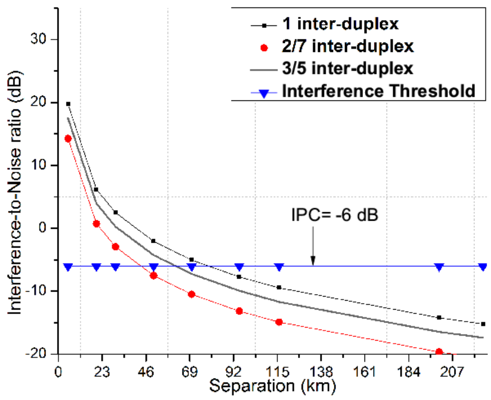
Parameter	Value
Frequency of operation (MHz)	2600
Transmission bandwidth (MHz)	1.4, 5, 10 and 20
Number of transmission antenna	1
Traffic Load	100%
Transmission Power (dBm)	43
Antenna Gain (dBi)	17
Antenna Height (m)	15
Receiver noise figure	5
ACIR	Retrieved from [16]
TDD subframe configurations	0 and 5

3. RESULTS AND ANALYSIS

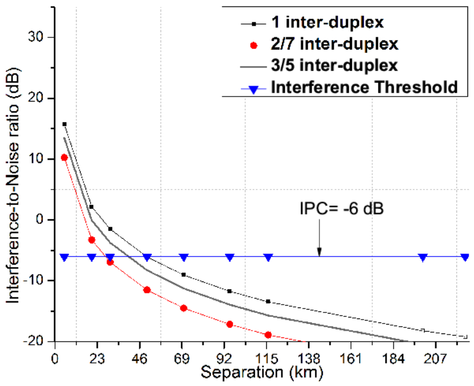
Figure 4 shows various scenarios of interfereneces for difference receiver bandwidths, namely 1.4, 5, 10 & 20, to highlight the effect of inter-duplex overlap on required coexistence separations. Three inter-duplex factors are chosen, i.e. 1, 2/7 & 3/5 ,respectively. Meanwhile, Interference protection criterion of -6 dB is assumed as discussed before.



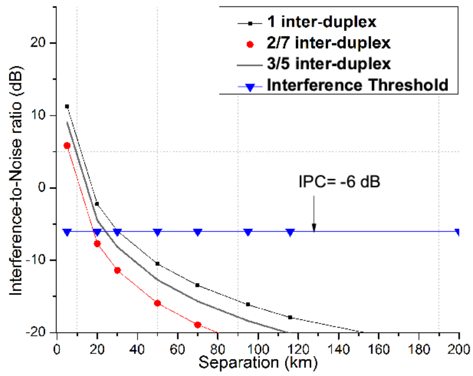
(a)



(b)



(c)



(d)

Figure 4. Impact of inter-duplex overlap factor on separation distance when 5 MHz aggressor interfers with a) 1.4 MHz victim b) 5 MHz victim c) 10 MHz victim d) 20 MHz victim

Figure 4 (a) where the victim receiver bandwidth equals to 1.4 MHz. Here, one can notice that value of $Int_{dup}=1$ requires more terrestrial separation than both duplex overlaps of 3/5 & 2/7. While $Int_{dup}=3/5$ needs more geographic distance than $Int_{dup}=2/7$.

Moving to Figure 4 (b) in which the victim's bandwidth is 5 MHz, while the same inter-duplex factors are considred. While the case of $Int_{dup}=1$ desires in more distance in between base stations than duplex overlaps of 3/5 & 2/7, however, owing to the 5 MHz bandwidth, it requires less separation as compared to 1.4 MHz of victim bandwidth for the same inter-duplex factor.

Similary, Figure 4 (c) & (d) display terrestrial distances required to protect victim receivers of 10 & 20 MHz bandwidths, respectively, from interfering transmitter. Likewise, it turns out that $Int_{dup}=1$ case needs less space in beteen affected base stations than those of 1.4 and 5 MHz.

Accordingly, it is clear that the bigger the receiver's bandwidth, the lesser the required separation. And that the bigger the inter-duplex factor, the more space needed in between cells. In other words, receiver's bandwidth is inversely proportional to terrestrial separations required in between affected cells.

4. CONCLUSION

This work brought forward the importance of duplex modes of cellular base stations in interference situations. The effect of inter-duplex overlap over the amount of emitted interference has been examined and analyzed. It is shown that interference is duplex-driven agent, and is always reduced by some factor unless similar duplexing frames are being overlapped. Due to the inclusion of duplex overlap in interference calculations, the methods proposed in this work produce more accurate deployment requirements as compared to the related literature.

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